

# WHAT IS A SOLENOID?

**Prepared by**



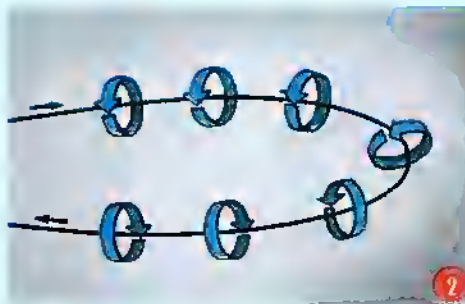
**to promote a better understanding of the  
basic operation of AC Industrial Grade Solenoids**

# WHAT IS A SOLENOID?

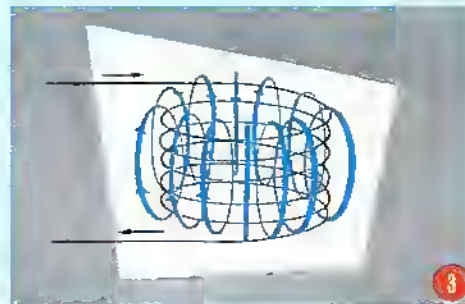
Decco®



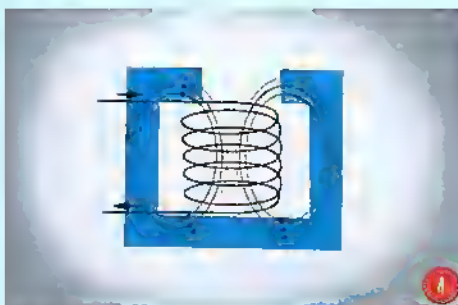
A solenoid is simply a specially designed electro-magnet. Here's how it works.



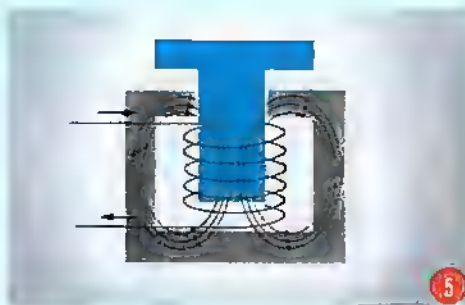
When current flows through a wire, a magnetic field is set up around the wire.



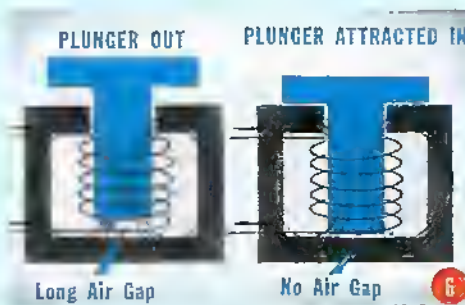
If we make a coil of many turns of wire this magnetic field becomes many times stronger, flowing around the coil and through its center in a doughnut shape.



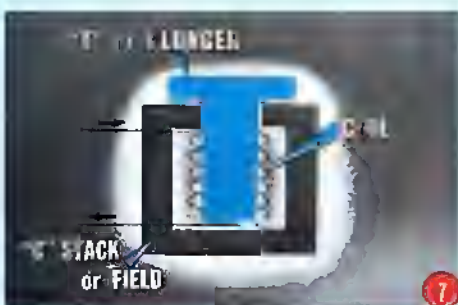
Although this magnetic field will flow in air, it flows much more easily through iron or steel – so we add an iron path, or "C" stack around the coil which concentrates the magnetism where we want it.



If we also add an iron path, known as a "T" or plunger, in the center of the coil, the magnetism is concentrated still more.



Because iron is an excellent magnetic conductor and air is a poor one, the movable iron "T" or plunger is drawn by the magnetic field into a position where the magnetism can travel 100% through the metal conductor.



With the addition of this movable plunger we have the basic solenoid as it is today.

Now, let's look at some refinements.



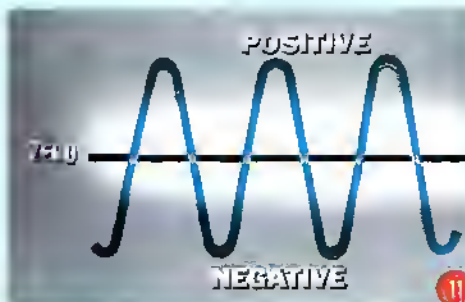
Remember, a solenoid operates because the magnetism tries to reduce the high resistance air gap at the bottom of the plunger. When the plunger is completely closed, the magnetic field flows 100% through a low resistance iron path.



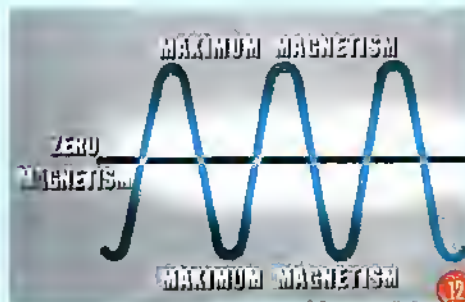
As the plunger is pulled into the coil, the air gap under the plunger is reduced, making the magnetic field stronger and increasing solenoid force. So ... as the solenoid closes, it becomes more powerful.



We have shown that a coil's magnetic field provides motion in only one direction – into the center of the coil. How, then, can we get a push and pull action? To pull, we simply hook on to the top of the plunger. We push from the bottom of the plunger.



An A.C. solenoid operates on current which looks like this. It alternates from positive through "zero" to negative sixty times a second.



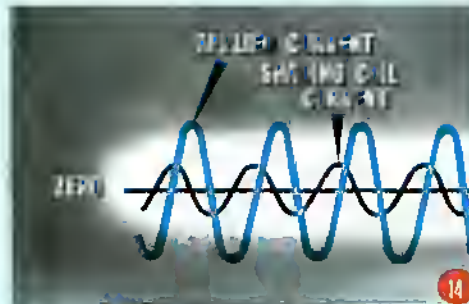
The magnetic field is strongest when the alternating current is at its positive and negative peaks. As the current goes through zero, the magnetism and solenoid force decrease, and the load forces the plunger out. When magnetism and force build up again, the plunger is pulled back in. This motion of the plunger, in and out, makes the solenoid buzz or chatter.



### SHADING COILS

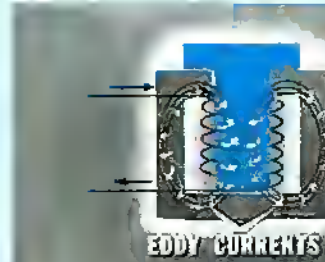


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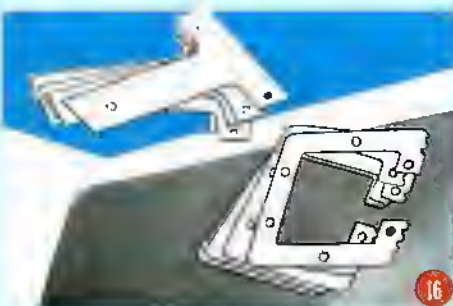
When the applied current is passing through zero, the shading coil current is at its maximum. This low shading coil current provides just enough magnetism to hold the plunger closed when applied current magnetism is at zero, thus eliminating the buzz.



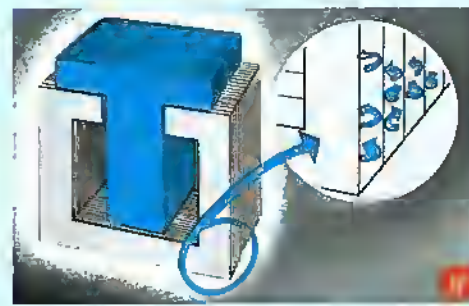
### EDDY CURRENTS

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A.C. magnetic fluctuations also cause small stray currents, known as "eddy currents", to move in tiny circular paths within the "C" stack and plunger. Eddy currents consume power and cause a heat build-up which reduces solenoid force. We must minimize them.

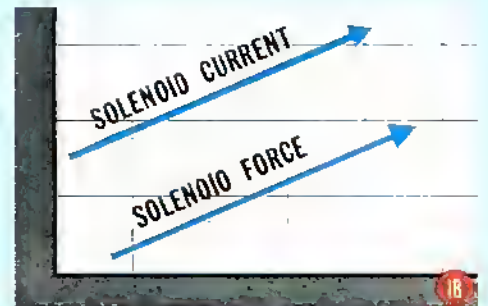


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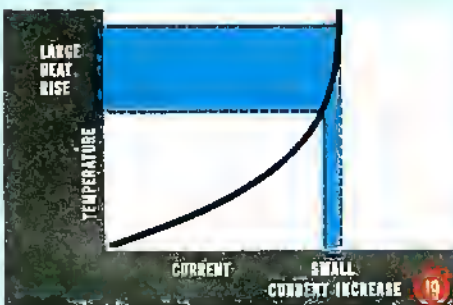
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Magnetism can easily flow in its usual path around the coil, but the eddy currents cannot flow from one lamination to another. By containing the eddy currents within each lamination, (limiting their paths), we reduce heating and increase solenoid force.

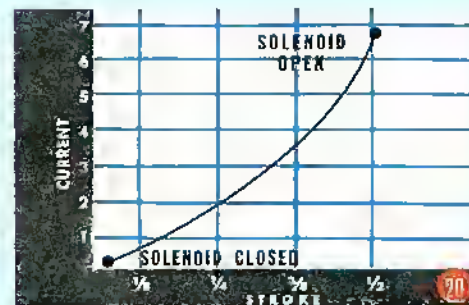


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Here's another important fact about solenoid operation. Increased current in a solenoid coil produces increased magnetism which increases solenoid force. So ... why don't we rig up a deal to ram all the current we can into a solenoid?



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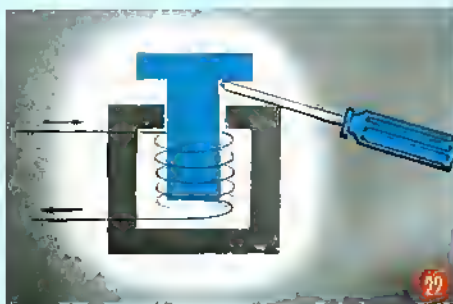
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As a solenoid closes, the flow of current decreases. The peak INRUSH CURRENT in the coil when the solenoid is open is several times greater than the "solenoid closed" HOLDING CURRENT due to A.C. resistance (or IMPEDANCE) which increases as the solenoid closes.

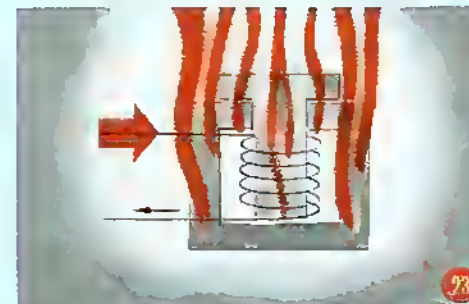


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Here is an analogy to help you fix this situation in your mind. Visualize current flowing to the coil through a rubber tube. This tube runs under the solenoid plunger. As the solenoid closes, it pinches the tube, reducing the flow of current to the coil.

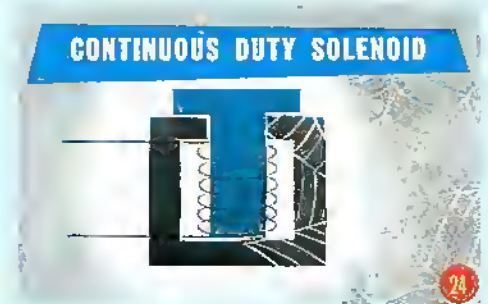


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This high current will generate more heat than the solenoid can dissipate. The coil wire insulation burns, the bobbin melts, and the coil shorts out - all in a minute or two. Applying too heavy a load to a solenoid will hold the plunger open in the same way.



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A CONTINUOUS DUTY SOLENOID is one that can be held energized indefinitely without overheating. The heat dissipating ability of this solenoid is great enough to get rid of all the heat generated by the coil's lower holding current.

Because current generates heat, and generates it fast. If you double the current you increase the heat four fold. A small increase in current causes a great rise in temperature, which can burn out a coil.

Remember - when a solenoid is open, it draws a high inrush current, which decreases as the solenoid closes. Now ... suppose we energize a solenoid, but mechanically block it open. The high inrush current will continue to flow in the coil.

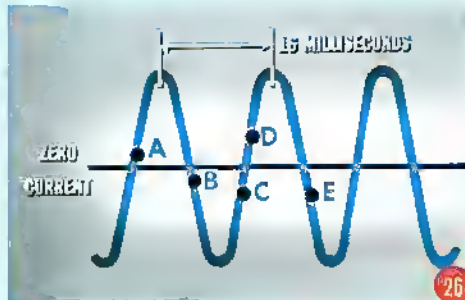


## INTERMITTENT DUTY SOLENOID



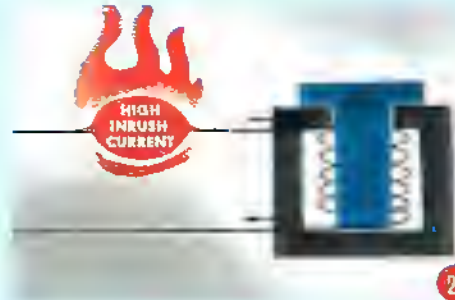
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We can get a large force from a small solenoid (by increasing the current) only if the application permits a very short solenoid "ON time" and a long "OFF time". This INTERMITTENT DUTY SOLENOID must be de-energized before it gets hot enough to burn up the coil. It cannot be continuously energized.



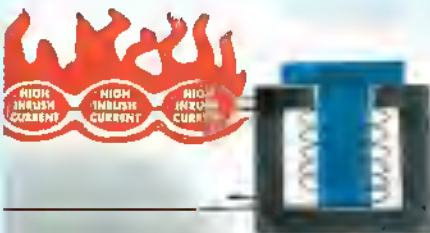
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An A.C. solenoid should close in approximately 8 to 16 milliseconds. A solenoid energized at Point A should close at Point B, (about 8 milliseconds). When energized at Point C, the solenoid may not start until Point D, and finish until Point E, (about 8 milliseconds).



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As a solenoid is cycled faster, its temperature rises and its force decreases. Each time a solenoid is cycled (or closed), it receives a high pulse of inrush current which generates heat in the coil. If these inrush pulses come fast enough...



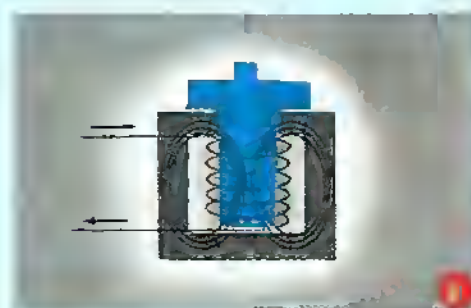
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...heat builds up faster than the solenoid can dissipate it. As the coil heats up, resistance increases, current flow and magnetism are reduced. The solenoid loses power and becomes too weak to close. The coil receives a continuous inrush current, and it burns out.



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99% of all U.S. power is 60 cycle frequency, and over 90% of all power outside the U.S. is either 50 or 60 cycle. A 60 cycle solenoid will overheat when operated on 50 cycles, and a 50 cycle solenoid will not produce rated force when operated on 60 cycles. Always use a coil designed for your specific power supply.



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To summarize ... a solenoid is simply a special electromagnet. Magnetism produced by the coil current draws the plunger into the coil, reducing the high resistance air gap, and allowing the magnetism to flow 100% through low resistance iron.



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We can make a solenoid pull by hooking onto the top of the plunger, or push from the bottom of the plunger.



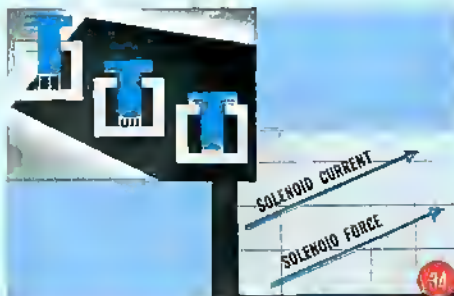
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Decco's copper shading coils keep a solenoid quiet by supplementing A.C. current fluctuations.



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Decco's insulated and laminated "C" stack and plunger reduce eddy currents and keep a solenoid cool.



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Solenoid force increases as the plunger closes – due to reduced air gap at the bottom of the plunger. Solenoid force also increases with an increase in coil current.



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When a solenoid is open, the inrush current is high, but drops as the solenoid closes.



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And finally – the faster you cycle a solenoid, the hotter it gets. If cycled too fast, it will overheat and burn out.

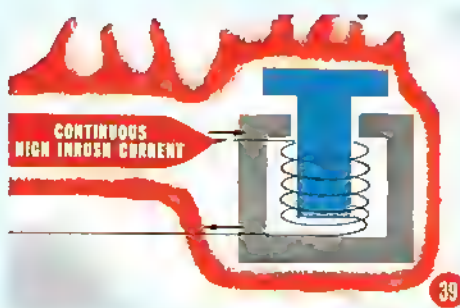


# SOLENOID TROUBLESHOOTING

The failure of an original equipment solenoid can usually be traced to some condition of the installation itself. These conditions are not overly difficult to spot. With a little practice, you can do your own solenoid troubleshooting.



Remember, when a solenoid is energized, the coil receives a pulse of high inrush current which decreases as the plunger closes.



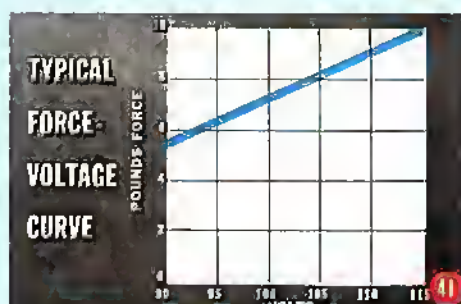
If, for any reason, the plunger does not close, the high inrush pulse continues, and the coil overheats and burns out. This type of coil burnout is the most common cause of solenoid failure. It's easy to spot. Here's how...



Standard DECCO coils are rated class 105°C. which means that they can safely reach and sustain temperatures up to 105° Centigrade, (or 221° Fahrenheit) — temperatures hotter than boiling water! Therefore, a solenoid too hot to touch may not be overheated!



When a coil burns out, the bobbin melts and nylon runs into the space under the plunger. If you find melted bobbin material, check to see if the plunger was mechanically blocked open. On a double solenoid valve, see if both solenoids were energized at the same time.



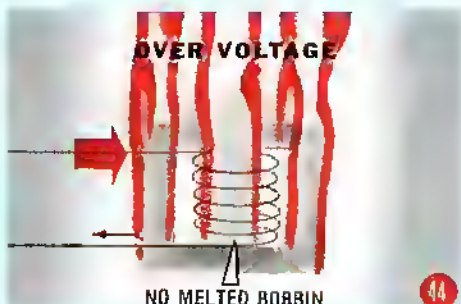
A drop in supply line voltage can prevent a solenoid from closing by reducing its force until it can't overcome the load. Check out the line voltage with a GOOD meter or have the local power company check your line voltage with a recorder over a 24-hour period.



Another thing to check is the ambient temperature. If the ambient is too high, the coil will lose its ability to dissipate heat. Resistance increases, current flow and force are reduced, and the solenoid will not close. Result — coil burnout.



And finally — check the cycling rate. If cycled too fast, heat will build up faster than it can be dissipated. The solenoid soon becomes too weak to close, receives a continuous inrush current, and burns out.



In rare cases, a solenoid coil will burn out due to OVER-VOLTAGE. The plunger WILL close, because the solenoid has extra force. (You'll find no melted bobbin.) The high voltage causes excessive holding current which will overheat the coil and burn it out.

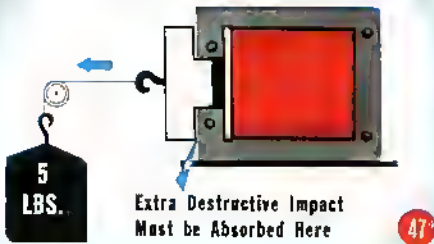


Another possible cause of coil burnout is SHORTING. Water base coolants often carry fine metallic particles from a grinder or other machine tool. Splashing or soaking can cause shorts between the coil's lead wire junctions.



This "C" stack and plunger were subjected to excessive force for a long period of time. Note the worn copper shading coils and the deep grooves in the "C" stack and plunger laminations. This causes the air gap at the base of the plunger to disappear.

# 10 POUND SOLENOID



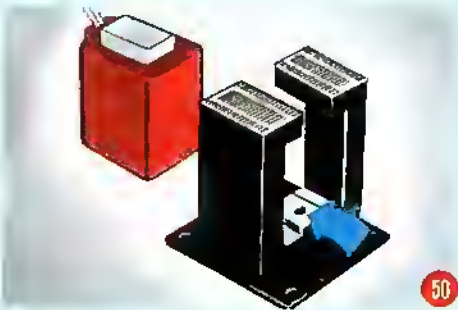
A solenoid can literally hammer itself to pieces. Excessive force can be caused either by overvoltage or by a reduced load on the solenoid, and must be absorbed when the plunger hits the "C" stack or field. Be sure the solenoid's force closely matches the load.



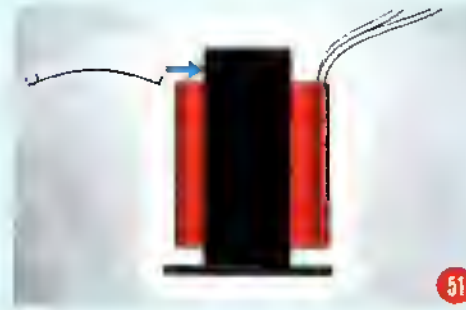
When you put everything together, you get a chart that looks like this.



Here's how to disassemble a Decco solenoid. Coils on Decco 01 and 02 models are held in place by a white nylon clip. To remove the coil, slide the nylon clip out by squeezing the locking ears together and pushing the clip out of the "C" stack.



Once the clip is out, lift the coil off the post at the bottom of the "C" stack and remove it.



When re-installing a coil in Decco 01 and 02 solenoids, push the nylon clip all the way in, in a "belly-up" position as shown. Make sure the locking ears snap outward to lock around the "C" stack.



On all other Decco solenoids, unscrew the two side plate bolts, spread the side plates from the bottom, and swing them up and off. Slide the coil out one side of the "C" stack. (It can only slide one way.) Replace the rubber bumpers in the backstop when re-assembling.

**When you call Decco...**  
 you'll talk to a real live person.  
 No annoying machines, no voice-mail jungle, no mind-boggling menus.  
 You will immediately be directed to an experienced solenoid specialist who will quickly help you solve your most difficult actuation problems.



Since "C" stack and plunger surfaces wear and match each other, they must be re-assembled exactly the same way they came apart. Reversing a plunger will cause chattering. Mark one side of the plunger and "C" stack with a grease pencil or chalk before disassembling.



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